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Occurrence and Uptake of Heavy Metals in Soil and Plant (Tomato) Associated with Crude Oil Contamination

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Abstract

The general increase of heavy metal content in the soil has been largely caused by crude oil spillage. This study investigates the possibility of tomato (*Lycopersicon esculentum* Miller) to sorb heavy metals present in crude oil. Crude oil of 0 mL (control), 75 and 150 mL were mixed thoroughly with 15 kg of loamy soil (dry weight) in perforated plastic buckets, as the experimental pots and left for 4 days before transplanting tomato seedlings. After 12 weeks of transplanting, heavy metals analysis was carried out on plant's fruits, leaves, stems and roots. Physicochemical analyses show that control soil had the lowest organic carbon (3.07 %) while 150 mL had the highest mean organic carbon content (8.24 %). The silt, clay and sand constituents were not significantly different ($p > 0.05$) in both treated and untreated soil. The control had the least pH value (6.1) while the lead (Pb) content in soil was highest in 150 mL (0.33 mg/kg) but was not significantly different ($p > 0.05$) from control (0.26 mg/kg) and 75 mL (0.30 mg/kg). Lead (Pb) and Cadmium (Cd) were not detected in leaves and fruits. However, bioaccumulation factor (BAF) of Cd and Ni in stem were greater than 1. Although, the concentrations of these heavy metals falls below toxic levels, its consumption could lead to adverse health effects in both man and animals through bioaccumulation or biomagnification.

Keyword: Heavy metals, Oil spillage, Soil pollution, Bioaccumulation, Ecotoxicity and Tomato

Introduction

Any metal or metalloid that contribute to ecotoxicity and contamination of the environment, no matter as little as its presence may be, is called heavy metal [1-3]. Nickel, Copper, Cadmium, Chromium, Zinc and Lead are examples of heavy metals that pollute the soil environment [4-6]. Although heavy metal contaminations in soil are traced to many sources, but large portions of them have been associated with crude oil spillage [7,8], since major stages of crude oil processes involve different metals. Crude oil gets to the environment through many ways such as operational discharge, during transportation, storage tanks and pipeline linkages, effluents from refinery and industry, atmospheric fall out, biosynthesis, accidental or indiscriminate discharges, and natural oil seepage [9,10]. It has therefore been observed that hydrocarbon laden soil harbor heavy metals, in quantities that could adversely affect plant growth and yield [11-13], alter soil composition and hinder the population and activities of vital soil dwellers [14,15].

Soil is a natural resource and an important factor greatly considered in the agricultural ecosystem. Its suitability and sustainability for cultivation largely depends on proper soil maintenance, which is absolutely necessary for agricultural productivity [16]. Countries with poor hydrocarbon pollution regulation are more challenged with oil spillage, either through accidental discharges or indiscriminate disposal of hydrocarbon waste. For example, the spill rampant crude oil producing areas in Nigeria, have recorded massive soil pollution with toxic metals and disrupted agricultural activities.

Plants essentially need some metals such as iron, copper among others, for their growth and other metabolic activities. However, at excess of specific limits, these metals adversely affect plant growth [17]. This heavy metal content of oil-contaminated soil imposes metabolic burden and growth inhibition on most of the plant species. Plant species strongly response differently in their anatomy and physiology to oil pollution [13]. According to Dulama *et al.* [18] and Oladejo *et al.* [19] plants species, plant age, plant part, soil composition, geographic and atmospheric conditions are factors that influence the rate of heavy metals absorption by plant.

After potato, tomato is the next most important food crop in the world [20]. It is a staple crop, with good source of vitamins and minerals for human consumption. Tomato is a useful ingredient for most African dishes, accounting for 18 % of vegetables consumed in Nigeria daily [21,22]. Due to its short shelf life, it can be processed into tomato paste, canned products, juices and even dried form. Apart from environmental stressors like drought and heat [23], the presence of heavy metals in the soil can also affect tomato production. Succulent tomato root can easily absorb toxic metals, accumulate it into plant system (**Figure 1**) and could be lurked in the food chain and consequently consumed by humans [24]. Their toxicity effect on human health can be acute or chronic, depending on their dosage, rate of emission and period of exposure [25]. There is a maximum acceptable limit for each heavy metal set by international organizations (WHO, FAO, US-EPA) for consumable crops and foods. Any value above the permissible value will often lead to adverse health effects such as neuromuscular changes, proteinuria, central nervous disorders, pneumoconiosis, encephalopathy, ulcer and cancer etc. on human [26,27]. Sobhanardakani *et al.* [28] opined that the acceptable limits for heavy metals in food samples is associated with low health risks in humans. The accumulation of permissible safe level of heavy metals in the body system over time, will be disadvantageous to health and it can cause serious illness. Hence, the aim of this study is to investigate the possibility of tomato absorbing heavy metals present in crude oil contaminated soil.

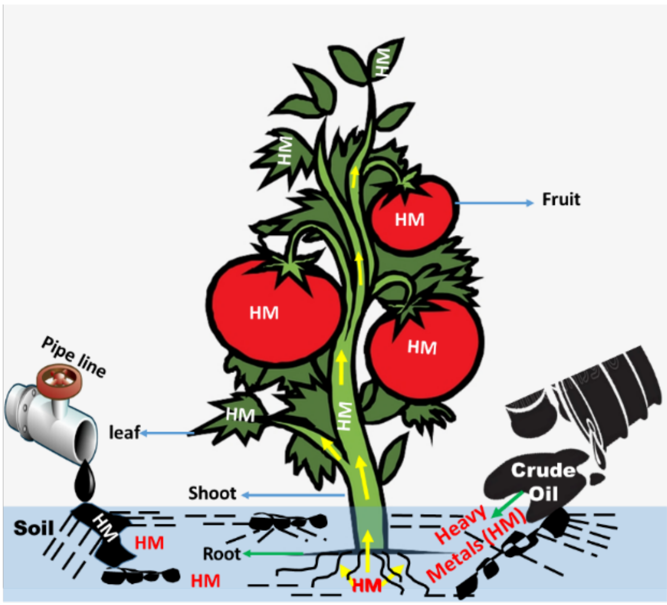

Figure 1 Graphic presentation of heavy metal accumulation in plant.

Methodology

Seedling preparation, soil amendment and transplanting

Germination test was conducted on tomato seeds in the laboratory before they were planted and raised for 5 weeks to get viable tomato seedlings. After this, 3 volumes of crude oil; 0, 75 and 150 mL were mixed thoroughly with 15 kg of loamy soil (dry weight) in perforated plastic buckets (experimental pots) and left for 4 days before transplanting viable tomato seedlings from nursery into the experimental pots (contaminated and uncontaminated (control)) soil. The plants were then watered every 3 days. Each treatment had 4 replicates and were arranged in a Completely Randomized Design (RCD). RCD means each experimental unit was randomly place in the experimental set up in such that each unit has the same chance of receiving any one treatment. The experimental set up was monitored for 12 weeks post transplanting inside a screened house.

Determination of plant heavy metals

Heavy metals analysis was carried out on plants fruits, leaves, stems and roots.

Plant sample preparation

The 2 g of pulverized sample was put into a conical flask, 10 mL of HNO_3 was added, and the mixture was boiled with steady heat till almost dried and cooled; 50 mL distilled water was added to it, boiled, cooled and filtered. The filtrate was made up to a known volume before metal analysis. The heavy metals analysis was done using Atomic Absorption Spectrophotometer-Buck Scientific 210 VGP model.

Quality control

This was done to ensure reliability of the study results. All reagents and chemicals used were of better grade and high purity. Plastic containers and glassware used were first thoroughly clean with detergent and rinsed several times, using distilled water before use. The instrument was first calibrated with already prepared working standard of corresponding elements to be analysed, after which the concentration of the element in each sample was determined:

$$\text{Heavy metal concentration (mg/kg)} = \frac{\text{reading} \times \text{Dilution Factor}}{\text{Weight of Sample}}$$

Soil analysis

Analysis carried out to determine soil parameters includes:

Determination of soil pH

The 20 g of air dried soil was sieved and 50 mL of distilled water was added to it and allowed to stand for 30 min. Using a glass rod, the mixture was stirred occasionally. The pH was determined using a pH meter (pH-2 Hanna) which was standardized with buffer 4 solution.

Determination of nitrogen

This was done by digesting the soil samples and titrating against 0.1 m HCL acid. The 10 mL of the digested soil was put in a conical flask, 2 to 5 drops of methyl orange indicator was added. The burette containing 0.1 M HCL was then titrated against the soil sample until a bluish coloration was seen:

$$\text{Nitrogen (\%)} = \frac{\text{Titre value} \times \text{volume of acid} \times \text{atmospheric nitrogen} \times \text{dilution factor}}{\text{Weight of Sample}} \times 100$$

Determination of soil organic carbon

Organic content of soil samples was analyzed using Wakley and Black wet oxidation method. The method measures active and decomposable organic matter in the soil. Oxidizable matter in the soil sample was oxidized by CrO_7^{2-} and the reaction is facilitated by the heat generated when 2 volumes of $Fe_2H_2SO_4^-$ were mixed with 2 volume of 1 mL normal $K_2CrO_7^{2-}$ solution. The excess CrO_7^{2-} was determined by titration with standard $FeSO_4$ solution and the quantity of substances oxidized was calculated from the amount of CrO_7^{2-} reduced, using n-phenonthroline (Ferrous complex indicator) giving colour change from blue to red:

$$\text{Equivalent weight} = \frac{\text{Atomic number of Carbon}}{\text{Valency of Carbon}}$$

Procedure for soil titration

The 10 g of 0.5 mm finely sieved soil (containing 10 - 25 mg of carbon) were weighed into 3 conical flasks. The 10 mL potassium dichromate solution and 20 mL of concentrated H_2SO_4 were added into each flask. The mixtures were shaken for 1 min and allowed to stand for 30 min on an asbestos mat away from drought and heat. Subsequently, 20 mL of water and 2 mL of phenonthroline indicator were added to each flask. The resultant solution was titrated against a ferrous sulphate solution. The solution will usually turn from purple to a bluish lavender colour near the end point. Thereafter, ferrous sulphate solutions was added slowly and then drop by drop, allowing about 30 s between drops until the last trace of blue disappears and colour becomes green:

$$\text{Organic carbon (\%)} = \frac{\text{Titre value} \times \text{atomic carbon} \times \text{correction factor} \times 100 \times 1.729}{\text{Weight of sample}}$$

Correction factor = 1.33 (standard)

Determination of phosphorus

Phosphorus (P) analysis was carried out by BrayP-1 method. Digestion was done with $HClO_4$ and phosphorus concentration was determined using spectrophotometer.

This was done using the visible spectrophotometer set at a wavelength of 420 nm:

$$\text{Solution (mg/kg)} = \frac{\text{R} \times \text{V} \times \text{D}}{\text{Weight of sample}}$$

where R = Graph reading,
V = volume of soil used,
D = Dilution factor.

Determination of soil heavy metal content

The 1 g of soil sample was digested in 10 mL aqua regia. The solution was boiled with steady heat until clear, allowed to cool, after which 50 mL of distilled water was added. The heavy metal analysis was carried out using Atomic Absorption Spectrophotometer-Buck Scientific 210 VGP model. The instrument was first calibrated with already prepared working standard of corresponding elements to be analysed after which the concentration of the element in each sample was determined:

$$\text{Concentration (mg/kg)} = \frac{\text{Reading} \times \text{dilution factor}}{\text{Weight of Sample}}$$

Translocation factor (TF) was calculated as the ratio of heavy metal concentrations in plant shoot to those in the corresponding root:

$$\text{TF} = \frac{Concentration\ of\ heavy\ metal\ in\ shoot}{Concentration\ of\ heavy\ metal\ in\ root}$$

Bioaccumulation factor (BAF) was calculated as the ratio of heavy-metal concentrations in plant shoot to those in the corresponding soil:

$$\text{BAF} = \frac{Concentration\ of\ heavy\ metal\ in\ shoot}{Concentration\ of\ heavy\ metal\ in\ Soil}$$

Data analysis

All data obtained were subjected to Analysis of Variance (ANOVA), where significant differences exist, treatment means were compared at 0.05 significant level using Tukey's HSD (Honest Significant Difference) and LSD (Least Significant Differences). SPSS 21.0 software was used for all statistical analysis.

Results and discussion

Physicochemical properties of contaminated and uncontaminated soil

The soil used for this experiment was a loamy soil. The organic carbon content of the soil was significantly different in all treatments at $p < 0.05$ using Tukey's HSD (Honest Significant Difference) (**Table 1**). The control had the lowest organic carbon (3.07 %) while 150 mL had the highest mean organic carbon content (8.24 %). The available phosphorus (P) decreased as the concentration of crude oil increased and there was significant difference ($p < 0.05$) among control (163.70 ppm), 75 mL (141.84 mg/kg) and 150 mL (101.35 mg/kg). The amendment of crude oil to soil was observed to increase the total nitrogen (N) in the soil. Control (0.01 %) had the least nitrogen while 150 mL (0.032 %) had the highest. The silt, clay and sand constituents were not significantly different ($p > 0.05$) in both treated and untreated soil.

Table 1 Physicochemical properties of contaminated and uncontaminated soil.

Concentration (mL)	Organic Carbon (%)	Phosphorus (mg/kg)	Nitrogen (%)	Sand	Clay	Silt (%)
Control	3.07 ± 0.04[a]	163.70 ± 1.73[c]	0.01 ± 0.001[a]	12.49 ± 0.03[a]	7.21 ± 0.12[a]	78.83 ± 0.69[a]
75 mL	5.46 ± 0.27[b]	141.84 ± 0.12[b]	0.02 ± 0.002[b]	11.65 ± 0.01[a]	7.37 ± 0.02[a]	80.10 ± 0.06[a]
150 mL	8.24 ± 0.12[c]	101.35 ± 0.23[a]	0.032 ± 0.001[c]	11.51 ± 0.58[a]	7.36 ± 0.01[a]	80.09 ± 0.01[a]

Mean ± standard error represents 4 replicates. Means value with the same alphabet down the column are not significantly different ($p > 0.05$).

Effect of crude oil contamination on soil pH

The control had the least pH value (6.1) and 150 mL treatment had the highest mean pH value (7.53). The control pH was significantly different ($p < 0.05$) from treated soils (**Figure 2**).

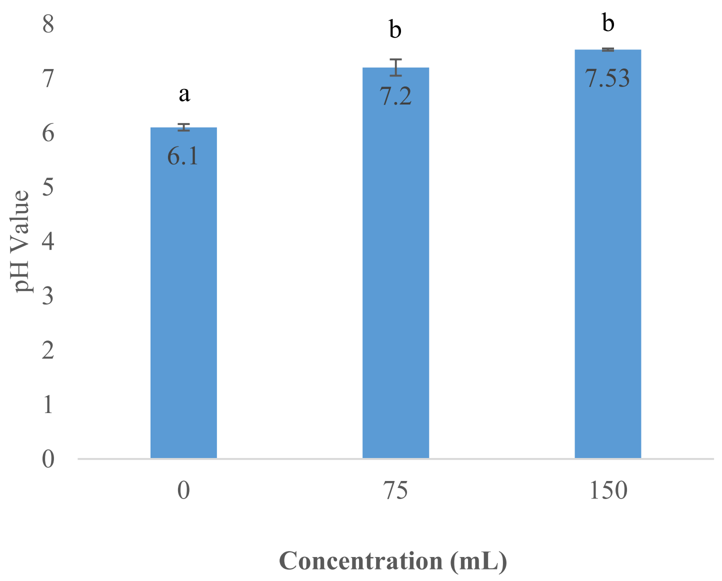

Figure 2 Effect of crude oil contamination on soil pH (The bars having the same alphabet on top are not significantly different ($p > 0.05$)).

Heavy metals concentration in contaminated and uncontaminated soil

In **Table 2**, the lead (Pb) content was highest in 150 mL (0.33 mg/kg) but was not significantly different ($p > 0.05$) from control (0.26 mL) and 75 mL (0.30 mg/kg). Iron (Fe) value recorded in 75 mL (61.75 mg/kg) was not significantly different ($p > 0.05$) from 150 mL treated soil (62.26 %). The concentration of cadmium (Cd) was highest in 150 mL treatment (0.050 mg/kg) but was not significantly different ($p > 0.05$) from control (0.012 mg/kg) and 75 mL (0.020 mg/kg). The lowest value (0.09 mg/kg) of zinc (Zn) was observed in the control while the highest value was in 150 mL (0.32 mg/kg). The manganese (Mn) content in the 75 mL treatment (2.70 mg/kg) was not significantly different ($p > 0.05$) from the control (2.07 mg/kg). The concentration of copper (Cu) in 150 mL (0.14 mg/kg) treated soil was significantly different ($p < 0.05$) from untreated soil (0.04 ppm), likewise in nickel concentration (0.18 mg/kg and 0.08 mg/kg respectively). The chromium (Cr) content in control (0.13 mg/kg) was lower but not significantly different ($p > 0.05$) from 75 mL (0.21 mg/kg) and 150 mL (0.26 mg/kg).

Table 2 Heavy metals concentration in contaminated and uncontaminated soil before planting.

Concentration (mL)	Heavy metals (mg/kg)							
	Pb	**Fe**	**Cd**	**Zn**	**Mn**	**Cu**	**Ni**	**Cr**
Control	0.26 ± 0.01[a]	58.04 ± 0.03[a]	0.012 ± 0.002[a]	0.09 ± 0.01[a]	2.07 ± 0.02[a]	0.04 ± 0.01[a]	0.08 ± 0.01[a]	0.13 ± 0.01[a]
75 mL	0.30 ± 0.06[a]	61.75 ± 0.03[b]	0.02 ± 0.006[a]	0.30 ± 0.01[b]	2.70 ± 0.40[a]	0.08 ± 0.01[ab]	0.13 ± 0.02[ab]	0.21 ± 0.06[a]
150 mL	0.33 ± 0.01[a]	62.26 ± 0.33[b]	0.05 ± 0.005[b]	0.32 ± 0.01[b]	3.81 ± 0.11[b]	0.14 ± 0.02[b]	0.18 ± 0.02[b]	0.26 ± 0.03[a]

Mean ± standard error represents 4 replicates. Means value with the same alphabet down the column are not significantly different ($p > 0.05$).

Concentration of heavy metals in tomato plant parts in the contaminated soil (75 mL crude oil)

Table 3 compared the heavy metals in different parts of tomato plant planted on soil contaminated with 75 mL crude oil. Lead (Pb) and Cadmium (Cd) were not detected in leaves and fruits. The highest content of chromium was recorded in the stem (0.14 mg/kg) but not significantly different ($p > 0.05$) from root (0.09 mL). There was no significant difference ($p > 0.05$) in copper (Cu) content among stem (0.05 mg/kg), root (0.03 mg/kg) and fruit (0.02 mg/kg). The least Nickel (Ni) content was in fruit (0.01 mg/kg) but not significantly different ($p > 0.05$) from leaves (0.08 mg/kg) and root (0.04 mg/kg). Lead (Pb) was recorded in stem (0.03 mg/kg) and root (0.01 mg/kg). Cadmium (Cd) content in stem was 0.010 mg/kg and 0.011 mg/kg in root.

Table 3 Concentration of heavy metals in tomato plant parts in the contaminated soil (75 mL crude oil).

Plant Parts	Heavy metals (mg/kg)				
	Cr	Cu	Ni	Pb	Cd
Leaves	0.05[a]	0.20[b]	0.08[ab]	nd	nd
Stem	0.14[b]	0.05[a]	0.25[b]	0.03	0.010
Root	0.09[ab]	0.03[a]	0.04[a]	0.01	0.011
Fruit	0.01[a]	0.02[a]	0.01[a]	nd	nd
LSD	0.059	0.059	0.146	-	-

LSD - Least significant difference, nd - not detected. Means value with the same alphabet down the column are not significantly different ($p > 0.05$).

Concentration of heavy metals in tomato plant parts in the contaminated soil (150 mL crude oil)

Table 4 compared the heavy metals in different parts of tomato plant planted on soil contaminated with 150 mL crude oil. Lead (Pb) and Cadmium (Cd) were not detected in leaves and fruits. The highest content of chromium was recorded in the stem (0.22 mg/kg) but not significantly different ($p > 0.05$) from root (0.15 mL). There was no significant difference ($p > 0.05$) in copper (Cu) content among stem (0.07 mg/kg), root (0.05 mg/kg) and fruit (0.01 mg/kg). The least Nickel (Ni) content was in fruit (0.01 mg/kg) but significantly different ($p < 0.05$) from other parts. Lead (Pb) was recorded in stem (0.06 mg/kg) and root (0.03 mg/kg). Cadmium (Cd) content in stem was 0.06 ppm and 0.03 pm in root.

Table 4 Concentration of heavy metals in tomato plant parts in the contaminated soil (150 mL crude oil)

Plant Parts	Heavy metals (mg/kg)				
	Cr	Cu	Ni	Pd	Cd
Leaves	0.07[ab]	0.28[b]	0.37[c]	nd	nd
Stem	0.22[c]	0.07[a]	0.46[d]	0.06	0.06
Root	0.15[bc]	0.05[a]	0.15[b]	0.03	0.03
Fruit	0.02[a]	0.01[a]	0.01[a]	nd	nd
LSD	0.084	0.103	0.059		

LSD - Least significant difference, nd - not detected. Means value with the same alphabet down the column are not significantly different ($p > 0.05$).

Heavy metals bioaccumulation and translocation factor in tomato plant

Bioaccumulation and translocation factor of heavy metals in tomato plant, using maximum concentration (150 mL) result was shown in **Table 5**. Bioaccumulation of Cadmium (Cd) (1.20) and Nickel (Ni) (2.56) was above 1 and also Translocation factor of all the heavy metals observed were above 1.

Table 5 Bioaccumulation and translocation factor.

	Heavy metals				
	Pb	**Cu**	**Cd**	**Ni**	**Cr**
BAF	0.18	0.50	1.20*	2.56*	0.85
TF	2.00*	1.40*	2.00*	3.07*	1.47*

***** The value above 1.

Discussion

In this study, heavy metals were detected in root, stem, leaves and even fruits of tomatoes planted in soils contaminated with crude oil. This shows the evidence that heavy metals in polluted soils can easily be absorbed and accumulated in plant parts. The presence of these heavy metals in the soil also increased as the quantity of crude oil in the soil increases. This occurrence has acute and chronic effect on plant metabolisms and responses, such as experiencing oxidative stress; lipid peroxidation, presence of malondialdehyde and disrupting the electron transport chain [5]. Elevated heavy metal concentration in the soil can lead to enhanced crop uptake and excessive metals intake in human nutrition, which can lead to acute gastrointestinal problems, respiratory damage, as well as acute heart, brain and kidney malfunction [29,30]. Many industrial activities of man have been attributed to heavy metal contamination of soil and plants in the environment, starting from the process, to the usage and waste disposal methods. Abiya *et al*. [31] reported the presence of heavy metals in the soil and on plants at a mining site in Nigeria. Ali and Al-Qahtani [32] also liken the highest value of some heavy metals detected in vegetables, cereals and fruits in Saudi Arabian markets to be due to heavy industrial activities and heavy traffic in middle and eastern districts of the country.

Furthermore, the results revealed that the presence of crude oil in the soil altered the physicochemical properties of the soil. This concurred with Ohanmu *et al.* [10] that oil pollution alters the physical and chemical nature of soil, which affect the growth of plant subsequently. The organic carbon present in the contaminated soil was higher when compared to uncontaminated soils. Apart from the fact that organic carbon can be added into the soil through microbial biomass, peat formation, plant fine root turnover and others, crude oil contamination also contributes to the increase in the total organic carbon in the soil. Increase in total organic carbon is an indicator for petroleum hydrocarbon contamination because total organic carbon includes all weight fractions of total petroleum hydrocarbons. Likewise, the pH value was also higher (less acidic) than in uncontaminated soil. It was reported by Vwioko *et al.* [33] and Marinescu *et al*. [34] that contamination of soil with crude oil increases its pH from acidic to neutral/alkaline. In contrast, Okoro *et al*. [35] reported the mean pH of soil samples collected around damaged pipeline to be 5.93 ± 0.18, compared to 6.16 of the control soil. Although, the maximum pH recorded in their study is 6.65. Change in pH of the soil contaminated with hydrocarbon oil may be due to the hydrophobic nature hydrocarbon oil, impossibility of basic salts that can raise soil pH to penetrate due to soil blockage by residual hydrocarbon, and also microorganisms' activities can lead to production of organic acid in the region [35]. In addition, soil pH has also been found to be a major factor influencing microorganisms and elements availability in soil, and plant uptake [10,36,37].

It is commonly found that roots have the highest value of heavy metals than any other parts, because root parts have direct contact with contaminated soil, absorb the metals present and translocate to other parts of the tomato plants. However, in this study, the stem recorded the highest values in all of the heavy metals except in copper (Cu). The highest value recorded in tomato stem may be due to the fact that some plants do not only accumulate metals in the roots but also on other parts of the plant [38]. Though, Murtić *et al.* [39] mentioned Cr and Ni to be 10 to 15-fold higher in the root than in other parts of tomato plants examined on a greenhouse soil.

Copper (Cu) was found to be highest in leaves for both crude oil contaminations examined. This agree with the fact that copper is very important in photosynthesis process of the plant's leaves and growth. Furthermore, Cu involve in activating enzymes activities, protein synthesis, lipid, nucleic and carbohydrate metabolism [37] but becomes toxic when it exceeds the limit of 20 mg/kg. Lead (Pb) and cadmium (Cd) were not present in leaves and fruits of the tomato planted for this experiment. Meanwhile, lead and cadmium have been reported to accumulate in plant and they either prevent mineral uptake or plant death [40]. Lead is a toxic element for life and environment, its presence should not exceed maximum acceptable limit (0.3 mg/kg) of European Regulation [41]. Patra *et al.* [42] opined that lead accumulate in the root and have small amount translocate to the aerial parts of the plant. According to He *et al*. [43], lead affects plant's germination, growth, photosynthesis, water regime, mineral nutrition and enzyme activity. Presence of Cr can also compromise germination, growth parameters (root, stem and leaf), and physiological processes in plants (Photosynthesis, mineral Nutrition, enzyme activities, and cell cycle) [44]. The heavy metals recorded in the fruit were chromium (Cr), copper (Cu), nickel (Ni) and were not above maximum acceptable limits [45]. Furthermore, it was observed that fruits were also reduced in sizes compare to tomato fruit on uncontaminated soil. Pollution caused by heavy metals does not only result in adverse effects on various parameters relating to plant quality and yield but also causes changes in the size, composition and even activity of the microbes in soil [46]. The reason being that crude oil form a film network (hydrophobic layers) that limit water penetration into the soil and as well as a barrier between root tip and soil for the uptake of nutrient.

Bioaccumulation factor (BAF) of Cd and Ni in stem were greater than 1, this shows that the tomato plant is a hyperaccumulator of Cd and Ni from the soil. Cd and Ni contents observed in the stem were greater than the content recorded in the contaminated soil. Nickel was also affirmed by Correia *et al*. [47], to accumulate in tomato plant planted on a contaminated soil. Although, it was reported to be in a low quantity that pose no risk to human health. The studied plant (Tomato) also displayed an efficient metal transport system, as its translocation factors (TF) calculated were above 1. This show that the plant accumulates metals in the shoot than root. However, Cr was noted to accumulate mainly in the roots and small part is translocate to the shoots, giving accumulating order of roots > stem > leaves > seed [44,48,49]. Many factors were considered to influence the uptake and accumulation of heavy metals from soil to the plant parts. Such contributing factors are soil type, pH and organic matter, plant species, chemical forms of the heavy metals, source of water for irrigation, and climatic condition [50,51]. Yoon *et al.* [46] stated that bioaccumulation factor (BAF) and translocation factor (TF) can be used to evaluate plant phytoremediation potential. Aladesanmi *et al.* [5] suggested that plant crops with high capacities to absorb heavy metals like Cd, Zn and Ni should be avoided during crop selection to prevent accumulation in human and its health risk. According to Adimalla *et al*. [52], human health risk pose by ingestion of heavy metals can be classified into carcinogenic and non-carcinogenic risk. Furthermore, International agency for Research on Cancer [53] considered Ni, Cd, Cr and As as category 1 of heavy metals, and Kim *et al*. [54] discussed the mechanism of their carcinogenicity. On the other hand, Yua *et al.* [55] considered Ni, Cd, Cr As Cu, Hg and Pb to have chronic non-carcinogenic health risks. Inhalation or ingestion of Ni has been related to asthma, cardiovascular disease, dermatitis, lung fibrosis, lung and nasal cancer [56,57]. Likewise, cadmium is considered to be a cumulative toxin and causes cancer of the liver, renal, prostate, bladder, lung, breast and stomach, as well as neurological disorder and reproductive system defects [58]. Again, eating Cr contained food crops can result into DNA damage, apoptosis, cell death, respiratory challenges, skin allergies, eye irritation, gastrointestinal, reproduction and cardiac disorder, teeth discoloration and cancer [59,60].

Conclusions

Heavy metals were absorbed by the roots of the plant studied and then translocated to other parts of the plants, thereby storing them in the tissues. Although, the concentrations of these heavy metals fall below toxic levels, but the consumption of such food crops could lead to adverse health effects in both man and animals through bioaccumulation or biomagnification. It is of concern that developing countries that are also oil producing countries are face with the heavy metal contamination of their soil and water. Although, it may be costly but there are remediation strategies that can remove heavy metals from the soil. So, crude oil pollution should be avoided and more novel strategies to remediate heavy metals from the environment should be researched and implemented.

References

[1] JH Duffus. "Heavy metals" a meaningless term? (IUPAC Technical Report). *Pure Appl. Chem.* 2002; **74**, 793-807.

[2] IY Zakka, KI Omoniyi and H Musa. A study of the uptake of heavy metals by plants near metal scrap dumpsite in Zaria, Nigeria. *J. Appl. Chem.* 2014; **2014**, 394650.

[3] H Ali, E Khan and I Ilahi. Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. *J. Chem.* 2019; **2019**, 6730305.

[4] V Masindi and KL Muedi. *Environmental contamination by heavy metals*. *In*: H El-Din M Saleh and RF Aglan (Eds.). Heavy metals. IntechOpen, London, 2018.

[5] OT Aladesanmi, JG Oroboade, CP Osisiogu and AO Osewole. Bioaccumulation factor of selected heavy metals in *Zea mays*. *J. Health Pollut.* 2019; **9**, 191207.

[6] J Briffa, E Sinagra and R Blundell. Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon* 2020; **6**, e04691.

[7] GO Anoliefo and DE Vwioko. Effects of spent lubricating oil on the growth of *Capsicum annum* L. and *Lycopersicon esculentum* mill. *Environ. Pollut*. 1995; **88**, 361-4.

[8] BS Al-Ali, HJ Al-Aradi, DD Al-Khion and HT Al-Saad. Petroleum hydrocarbons in water, soil and tomato plant (*Lycopersican esculentum* L.) at Basra City, Iraq. *J. Biol. Agr. Healthc.* 2016; **6**, 55-64.

[9] MRA Al-Qahtani. Effect of oil refinery sludge on plant growth and soil properties. *Res. J. Environ. Sci.* 2011; **5**, 187-93.

[10] EO Ohanmu, SP Bako, E Ohanmu and OO Ohanmu. Environmental implications, properties and attributes of crude oil in the oil-producing states of nigeria. *Ecologia* 2019; **9**, 1-9.

[11] BE Udom, AO Ano and W Chukwu. Contaminant limit (c/p index) of heavy metals in spent oil contaminated soil bioremediated with legume plants and nutrients. *J. Soil. Sci.* 2012; **22**, 144-52.

[12] FP Adesina and MO Ashamo. Assessment of growth of *D. bulbifera* (L.) on contaminated soil (Spent Engine Oil) and industrial effluent. *Int. Res. J. Environ. Sci*. 2019; **8**, 1-6.

[13] Y Olaranont, AB Stewart and P Traiperm. Effects of crude oil on plant growth and leaf anatomical structures in a common coastal plant. *Int. J. Phytoremed.* 2021; **23**, 162-70.

[14] F Abbasian, R Lockington, M Mallavarapu and R Naidu. A comprehensive review of aliphatic hydrocarbon biodegradation by bacteria. *Appl. Biochem. Biotechnol.* 2015; **176**, 670-99.

[15] RN Hazim and MA Al-Ani. Effect of petroleum hydrocarbons contamination on soil microorganisms and biodegradation. *Rafidain J. Sci.* 2019; **28**, 13-22.

[16] Food and Agriculture Organisation of the United Nations - FAO (2015), land and soils, Available at: http://www.fao.org/sustainable-development-goals/overview/fao-and-the-post-2015-development-agenda/land-and-soils/en, accessed April 2021.

[17] B Ikhajiagbe, GO Anoliefo, MA Jolaoso and EO Oshomoh. Phytoassessment of a waste engine oil-polluted soil exposed to two different intervals of monitored natural attenuation using african yam bean (*Sphenostylis stenocarpa*). *Pakistan J. Biol. Sci.* 2013; **16**, 680-5.

[18] ID Dulama, IV Popescu, C Stihi, C Radulescu, GV Cimpoca, LG Toma, R Stirbescu and O Nitescu. Studies on accumulation of heavy metals in Acacia leaf by EDXRF. *Rom. Rep. Phys.* 2012; **64**, 1063-71.

[19] N Oladejo, B Anegbe and O Adeniyi. Accumulation of heavy metals in soil and maize plant (*Zea mays*) in the vicinity of two government approved dumpsites in Benin City, Nigeria. *Asian J. Chem. Sci.* 2017; **3**, 1-9.

[20] RW Hammond. *Economic significance of viroids in vegetable and field crops.* Viroids Satellites 2017; 5-13.

[21] E Ebimieowei and E Ebideseghabofa. Postharvest quality of commercial tomato (*Lycopersicon Esculentum* Mill.) fruits brought into yenagoa metropolis from northern nigeria. *J. Biol. Agr. Healthc.* 2013; **3**, 49-54.

[22] AO Adepoju. Post-harvest losses and welfare of tomato farmers in ogbomosho, Osun state, Nigeria. *J. Stored Prod. Postharvest Res.* 2014; **5**, 8-13.

[23] NM Salem, LS Albanna and AM Awwad. Toxic heavy metals accumulation in tomato plant (*Solanum lycopersicum*). *ARPN J. Agr. Biol. Sci.* 2016; **11**, 399-404.

[24] FA Andal. Assessment of the possible utilization of tomato as a phytoremediant in soils artificially contaminated with heavy metals. *Int. J. Appl. Environ. Sci.* 2016; **11**, 193-209.

[25] GK Kinuthia, V Ngure, D Beti, R Lugalia, A Wangila and L Kamau. Levels of heavy metals in wastewater and soil samples from open drainage channels in Nairobi, Kenya: Community health implication. *Sci. Rep.* 2020; **10**, 8434.

[26] M Mahurpawar. Effects of heavy metals on human health. *Int. J. Res. Granthaalayah* 2015; **10**, 1-7.
[27] G Mansourri and M Madani. Examination of the level of heavy metals in wastewater of bandar abbas wastewater treatment plant. *Open J. Ecol.* 2016; **6**, 55-61.
[28] S Sobhanardakani, L Tayebi and SV Hosseini. Health risk assessment of arsenic and heavy metals (Cd, Cu, Co, Pb, and Sn) through consumption of caviar of *Acipenser persicus* from Southern Caspian Sea. *Environ. Sci. Pollut. Res.* 2018; **25**, 2664-71.
[29] GM Harry, SB Sujitha, MP Jonathan, SK Sarkar, MM Fairy, AM Helcias, MM Gladis and AM Laura. Mercury levels in human population from a mining district in western colombia. *J. Environ. Sci.* 2018; **68**, 83-90.
[30] A James, M Percy, OS Ameh and C Buggy. Heavy metals pollution status of the katima mulilo urban open land wastewater disposal centre and the immediate vicinity. *Cogent Environ. Sci.* 2020; **6**, 1726093.
[31] SE Abiya, BO Odiyi, FA Ologundudu, OJ Akinnifesi and S Akadiri. Assessment of heavy metal pollution in a gold mining site in Southwestern Nigeria. *J. Cell Biol. Genet.* 2018; **1**, 30-5.
[32] MHH Ali, KM Al-Qahtani. Assessment of some heavy metals in vegetables, cereals and fruits in Saudi Arabian markets. *Egypt. J. Aquat. Res.* 2012; **38**, 31-7.
[33] ED Vwioko, ME Osawaru and OL Eruogun. Nickel and chromium concentration in the plant tissues of six accession of okra (*Abelmoschus esculetus* L. Moench) grown in soil contaminated with paint waste. *Afr. J. Gen. Agr.* 2008; **4**, 27-37.
[34] M Marinescu, M Toti, V Tanase and V Carabulea. An assessment of the effects of crude oil pollution on soil properties. *Annu. Rev. Food Sci. Tech.* 2010; **11**, 94-9.
[35] D Okoro, PO Oviasogie and FE Oviasogie. Soil quality assessment 33 months after crude oil spillage and clean-up. *Chem. Speciation Bioavailability* 2011; **23**, 1-6.
[36] SP Bako, SJ Oniye and LSP Bako. Threat and potentials of invasive macrophtye species to inland freshwaters in relation to changing climate in Northern Nigeria. *In*: Proceedings of the 54th Symposium of the International Association for Vegetation Science, Lyon, France. 2011.
[37] E Ohanmu, S Bako and M Adelanwa. *Effect of oil spillage on the productivity of pepper (Capsicum spp).* Lambert Academic Publishing, Saarbrücken, Germany, 2017.
[38] AJ Baker, SP Megrath, M Reeves and JA Smith. *Metal accumulator review of the ecology and physiology of a biological resource for phytoremediation of metal polluted soils*. *In*: N Terry and G Banuelos (Eds.). Phytoremediation of contaminated soil and water, London, 2000.
[39] S Murtić, Ć Zahirović, H Čivić, L Karić and J Jurković. Uptake of heavy metals by tomato plants (*Lycopersicum esculentum* Mill.) and their distribution inside the plant. *Agr. Forest.* 2018; **64**, 251-61.
[40] V Radovanovic, I Djekic and B Zarkovic. Characteristics of cadmium and lead accumulation and transfer by chenopodium quinoa will. *Sustainability* 2020; **12**, 3789.
[41] United Nations Environment Programme. *Commission Regulation (EC) No. 1881/2006 setting maximum levels for certain contaminants in foodstuffs*. United Nations Environment Programme, Nairobi, Kenya, 2006, p. 5-24.
[42] M Patra, N Bhowmik, B Bandopadhyay and A Sharma. Comparison of mercury, lead and arsenic withrespect to genotoxic effects on plant systems and the development of genetic tolerance. *Environ. Exp. Bot*. 2004; **52**, 199-223.
[43] J He, ZX Ji, QZ Wang, CF Liu and YB Zhou. Effect of Cu and Pb pollution on the growth and antionxidant enzyme activity of *Suaeda heteroptera*. *Ecol. Eng*. 2016; **87**, 102-9.
[44] H Oliveira. Chromium as an environmental pollutant: Insights on induced plant toxicity. *J. Bot.* 2012; **2012**, 375843.
[45] World Health Organization. Summary and conclusions. *In*: Proceedings of the 53rd Meeting of the Joint FAO/WHO expert committee on food additives, Rome, Italy. 1999.
[46] J Yoon, X Cao, Q Zhou and LQ Ma. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. *Sci. Total Environ.* 2006; **368**, 456-64.
[47] L Correia, P Marrocos, DMM Olivares, FG Velasco, FHM Luzardo and RMD Jesus. Bioaccumulation of nickel in tomato plants: Risks to human health and agro-environmental impacts. *Environ. Monit. Assess.* 2018; **190**, 317.
[48] KK Tiwari, S Dwivedi, NK Singh, UN Rai and RD Tripathi. Chromium (VI) induced phytotoxicity and oxidative stress in pea (*Pisum sativum* L.): Biochemical changes and translocation of essential nutrients. *J. Environ. Biol*. 2009; **30**, 389-94.

[49] P Sundaramoorthy, A Chidambaram, KS Ganesh, P Unnikannan and L Baskaran. Chromium stress in paddy: (i) nutrient status of paddy under chromium stress; (ii) phytoremediation of chromium by aquatic and terrestrial weeds. *Compt. Rendus Biol.* 2010; **333**, 597-607.
[50] JE Gall and N Rajakaruna. *The physiology, functional genomics, and applied ecology of heavy metal-tolerant Brassicaceae*. *In*: M Lang (Ed.). Brassicaceae: Characterization, functional genomics and health benefits. Nova Science Publishers, New York, 2013, p. 121-48.
[51] S Neilson and N Rajakaruna. *Phytoremediation of agricultural soils: Using plants to clean metal-contaminated arable lands*. *In*: A Ansari, S Gill, R Gill, G Lanza and L Newman (Eds.). Phytoremediation: Management of environmental contaminants. Springer, Berlin, Germany, 2015, p. 159-68.
[52] N Adimalla. Heavy metals contamination in urban surface soils of medak province, India, and its risk assessment and spatial distribution. *Environ. Geochem. Health* 2020; **42**, 59-75.
[53] International Agency for Research on Cancer. *IARC monographs on the evaluation of carcinogenic risk to human*. International Agency for Research on Cancer, Lyon, France, 2012.
[54] HS Kim, YJ Kim and YR Seo. An overview of carcinogenic heavy metal: Molecular toxicity mechanism and prevention. *J. Canc. Prev.* 2015; **20**, 232-40.
[55] G Yua, F Chena, H Zhang and Z Wang. Pollution and health risk assessment of heavy metals in soils of Guizhou, China. *Ecosys. Health Sustain.* 2021; **7**, 1859948.
[56] QY Chen, T DesMarais and M Costa. Metals and mechanisms of carcinogenesis. *Annu. Rev. Pharmacol. Toxicol.* 2019; **59**, 537-54.
[57] G Genchi, A Carocci, G Lauria, MS Sinicropi and A Catalano. Nickel: Human health and environmental toxicology. *Int. J. Environ. Res. Publ. Health* 2020; **17**, 679.
[58] G Genchi, MS Sinicropi, G Lauria, A Carocci and A Catalano. The effects of cadmium toxicity. *Int. J. Environ. Res. Publ. Health* 2020; **17**, 3782.
[59] RT Achmad, Budiawan and EI Auerkari. Effects of chromium on human body. *Ann. Rev. Res. Biol.* 2017; **13**, 1-8.
[60] B Yaman. Health effects of chromium and its concentrations in cereal foods together with sulfur. *Expo. Health* 2020; **12**, 153-61.